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Concept Paper for an Encounter Response Protocol for Fisheries Management

Document de conception concernant un protocole d'intervention en cas de rencontre pour la gestion des pêches

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ABSTRACT

In 2009, Fisheries and Oceans Canada (DFO) introduced the Sustainable Fisheries Framework (SFF) to help ensure Canadian fisheries support conservation and sustainable use, and to align domestic policy with international obligations. One component of the SFF, the *Policy for Managing the Impact of Fishing on Sensitive Benthic Areas* (SBA policy), describes a five-step process to avoid serious or irreversible harm to sensitive benthic areas or species. These steps include: 1) assemble and map existing data and information to determine the distribution of sensitive benthic areas or species; 2) assemble and map existing information on fishing activities; 3) use an Ecological Risk Analysis Framework to assess the likelihood that a fishing activity causes harm to sensitive benthic areas or species; 4) determine whether management measures are needed and implement them where appropriate; and 5) monitor and evaluate the effectiveness of the management measure. In March 2011, a national Canadian Science Advisory Secretariat (CSAS) peer-review process was held in Ottawa to provide science advice on the ecological considerations relevant to developing a science-based encounter protocol framework to protect corals and sponges in Canadian waters from serious or irreversible harm. This paper reviews potential issues with implementing an encounter protocol, and provides a pragmatic encounter response assessment and management framework that could be implemented under the SBA policy to assist in domestic alignment with UNGA *Resolution 61/105.* The proposed encounter protocol has six components, which are closely aligned to the five process steps outlined in the SBA policy. Decisions to allow fishing and/or implement an encounter protocol are based on the calculated risk that fishing activity causes serious adverse impacts (SAIs) to vulnerable marine ecosystems (VMEs). The six components of the proposed encounter protocol are: 1) assemble and map VME distributions; 2) assemble and map the extent of human impacts; 3) infer the current VME status using VME and human impact distributions; 4) conduct a risk analysis; 5) determine management measures and implementation; and 6) monitor and evaluate responses. The proposed encounter protocol framework provides a potential assessment and decision making system, even for situations where there is limited data. It also provides an adaptable system which can be modified as new information becomes available.

RÉSUMÉ

En 2009, Pêches et Océans Canada (MPO) a présenté le Cadre pour la pêche durable pour aider à veiller à ce que les pêches canadiennes appuient la conservation et l'utilisation durable et harmoniser la politique nationale aux obligations internationales. Une composante du Cadre pour la pêche durable, la *Politique de gestion de l'impact de la pêche sur les zones benthiques vulnérables* (politique sur les zones benthiques vulnérables), décrit un processus en cinq étapes visant à éviter de causer des dommages graves ou irréversibles aux zones ou aux espèces benthiques vulnérables. Ces étapes sont les suivantes : 1) regrouper et cartographier les données existantes pour déterminer la distribution des zones ou espèces benthiques vulnérables; 2) regrouper et cartographier les renseignements existants sur les activités de pêche; 3) utiliser un cadre d'analyse du risque écologique pour évaluer la probabilité qu'une activité de pêche cause des dommages à des zones ou espèces benthiques vulnérables; 4) déterminer si des mesures de gestion sont nécessaires et, le cas échéant, les mettre en œuvre; 5) surveiller et évaluer l'efficacité des mesures de gestion. En mars 2011, le Secrétariat canadien de consultation scientifique (SCCS) a organisé un processus d'examen national par des pairs à Ottawa dont le but était de formuler un avis scientifique sur les considérations écologiques propres à l'élaboration d'un cadre scientifique pour un protocole en cas de rencontre afin de protéger les coraux et les éponges dans les eaux canadiennes contre les dommages graves ou irréversibles. Le document examine les problèmes éventuels de la mise en œuvre d'un protocole en cas de rencontre et offre une évaluation pragmatique du protocole d'intervention en cas de rencontre et un cadre de gestion qui pourraient être mis en œuvre dans le cadre de la politique sur les zones benthiques vulnérables pour favoriser l'harmonisation nationale avec la *Résolution 61/105* de l'Assemblée générale des Nations unies (UNGA). Le protocole proposé en cas de rencontre contient six composantes étroitement harmonisées au processus en cinq étapes indiqué dans la politique sur les zones benthiques vulnérables. Les décisions visant à permettre la pêche et/ou à mettre en œuvre un protocole en cas de rencontre sont fondées sur le risque calculé que l'activité de pêche cause des effets néfastes notables sur les écosystèmes marins vulnérables. Les six composantes du protocole proposé en cas de rencontre sont les suivantes : 1) regrouper et cartographier les distributions des écosystèmes marins vulnérables; 2) regrouper et cartographier l'ampleur de l'incidence humaine; 3) déduire l'état actuel des écosystèmes marins vulnérables à l'aide des distributions des écosystèmes marins vulnérables et des incidences humaines; 4) réaliser une analyse des risques; 5) déterminer les mesures de gestion et leur mise en œuvre; 6) surveiller et évaluer les interventions. Le cadre du protocole proposé en cas de rencontre offre un système éventuel d'évaluation et de prise de décision, même dans les situations où les données sont limitées. Il offre également un système adaptable pouvant être modifié au fur et à mesure que de nouveaux renseignements deviennent disponibles.

INTRODUCTION

Fisheries management has historically focused on the status and trends of target species, and the allowable impacts of fisheries on these species. Recently, however, fisheries management has begun to move from a single-species approach to a more holistic ecosystem approach. This shift to an ecosystem approach to management necessitates greater accounting for and managing of all of the pathways of effects a fishery has on an ecosystem, the effects of environmental forcers, and the impact of fisheries on stock dynamics. Management requests for advice on the impacts of specific fisheries on biodiversity, habitat, and ecosystem form and function pose new challenges to science. Data and our understanding of ecosystem processes are both incomplete, and the cumulative effects of multiple human activities and natural forces may reflect interactions and synergies that are difficult to disentangle. In addition, frameworks which integrate multiple objectives for human uses of ecosystems along with the resilience of those ecosystems to withstand perturbations are still in developmental stages, and are not ready for use in preparing advice.

In 2009, Fisheries and Oceans Canada (DFO) introduced the Sustainable Fisheries Framework (SFF) (DFO, 2009a). The SFF is intended to provide the basis for ensuring Canadian fisheries are conducted in a manner that supports conservation and sustainable use. The SFF strives to align domestic policy with the 2006 United Nations General Assembly (UNGA) *Resolution 61/105* and the resulting Food and Agriculture (FAO) *International Guidelines for the Management of Deep-Sea Fisheries in the High Seas*. The SFF includes a number of existing and new policies for fisheries management including the *Policy for Managing the Impact of Fishing on Sensitive Benthic Areas* (SBA policy) (DFO, 2009b) as well as tools to monitor and assess initiatives geared towards ensuring an environmentally sustainable fishery. The SBA policy is intended to help DFO manage fisheries to mitigate their impacts on sensitive benthic areas or avoid impacts that are likely to cause serious or irreversible harm to sensitive marine habitat, communities, and/or species. The *FAO Guidelines*, paragraphs 21 and 22 define significant adverse impacts as:

21. Adverse impacts caused by fishing gear or other anthropogenic disturbances are impacts on populations, communities, or habitats that are more than minimal and not temporary in nature. The impact will be adverse if its consequences are spread in space or through ecosystem interactions and are not temporary, even if the ecosystem feature that is directly impacted shows rapid recovery.

22. Adverse impacts become significant when the harm is serious or irreversible. Impacts that are likely to take two or more generations of the impacted populations or communities or more than 20 years (whichever is shorter) to reverse are considered irreversible. Impacts that are likely to reduce the productivity of any population impacted by the fishery (whether intentional or accidental); or the productivity, species richness, or resilience of an impacted community or ecosystem; or the structural complexity of a habitat are considered serious. In this context productivity is intended to mean all aspects of a population's capacity to maintain itself. In circumstances of limited information the assumption should be that impacts will be serious or irreversible unless there is evidence to the contrary.

For consistency with the FAO, this has been adopted as the working definition under the SBA policy for fishing impacts that are considered 'serious or irreversible'.

The SBA policy describes a five-step process to avoid serious or irreversible harm to sensitive benthic areas or species. These steps include 1) assemble and map existing data and information to determine the extent and location of sensitive benthic areas or species; 2) assemble and map existing information and data on fishing activities; 3) use of the Ecological

Risk Analysis Framework to assess the likelihood a fishing activity will cause harm to the sensitive benthic area or species; 4) determine whether management measures are needed and implement them where appropriate; and 5) monitor and evaluate the effectiveness of the management measure.

In March 2011 a national Canadian Science Advisory Secretariat (CSAS) peer-review process was held in Ottawa, Ontario to provide science advice on the ecological considerations relevant to the development of a science-based encounter protocol framework to protect corals and sponges in Canadian waters from serious or irreversible harm. This concept paper was prepared in preparation for that meeting.

The objectives of this paper are:

- To review potential issues with implementing an encounter protocol in the management of fisheries to mitigate fisheries' impacts on sensitive benthic areas or avoid impacts that are likely to cause serious or irreversible harm to sensitive marine habitat, communities, and/or species; and
- To provide a concept for a pragmatic encounter response assessment and management framework that could be implemented under the SBA policy to assist in domestic alignment with UNGA *Resolution 61/105.*

CURRENT SITUATION

UNGA *Resolution 61/105* calls upon States "*to take action immediately individually and through regional fisheries management organizations and arrangements (RFMO/A), and consistent with the precautionary approach and ecosystem approaches, to sustainably manage fish stocks and protect vulnerable marine ecosystems (VME) from destructive fishing practices…*". Some RFMO/As have responded to this directive by closing areas using various levels of precaution on known occurrences of vulnerable species or communities (as defined in the Annex of the FAO Guidelines). For areas where there is no information or where encounters are possible but uncertain, the approach has been to set catch thresholds to define an encounter and to specify measures that are applied if an encounter occurs. This is generally consistent with the FAO Guidelines, which specify that:

67. States and RFMO/As should have an appropriate protocol identified in advance for how fishing vessels in Deep Sea Fisheries (DSFs) should respond to encounters in the course of fishing operations with a VME, including defining what constitutes evidence of an encounter. Such protocol should ensure that States require vessels flying their flag to cease DSFs fishing activities at the site and report the encounter, including the location and any available information on the type of ecosystem encountered, to the relevant RFMO/A and flag State.

68. In designing such protocols and defining what constitutes an encounter, States and RFMO/As should take into account best available information from detailed seabed surveys and mapping, other relevant information available for the site or area, and other conservation and management measures that have been adopted to protect VMEs pursuant to paragraphs 70 and 71.

69. States and RFMO/As should, in light of reports (as referred to in paragraph 67), and in accordance with developed protocols and Section 5.2, adopt or modify management measures, appropriate for the DSF concerned, in regard to the relevant site or area to prevent significant adverse impacts on the VME.

In practice, RFMO/As define a VME encounter as bycatch of the taxa of concern meeting or exceeding a certain catch level. Nearly universally, a 'move-on rule' has been used as the management response, requiring that the fishing operation stops and the vessel moves at least a specified distance from the occurrence of the encounter.

Past advisory meetings have provided guidance on what constitutes a VME (DFO 2010a and Boutillier *et al.* 2010), and we will not reiterate that discussion here.

Auster *et al.* (2010) and Parker *et al.* (2009) outline a number of challenges with the implementation of an encounter response protocol including:

- Difficulty in detection of VME;
- Difficulty with setting thresholds for defining an encounter; and
- The nature and extent of management response (the 'move-on rule').

This paper will review the issues raised in those papers and discuss possible ways forward to address them.

DETECTION OF A VME REQUIRING A MANAGEMENT RESPONSE

There are three main issues related to the detection of a VME:

1. What constitutes an encounter between fishing gear and a VME in the water or on the seafloor?
2. What evidence may be available to the fishing operator and/or an observer to indicate that an encounter with a VME has occurred?
3. How does an operator or regulator know whether the evidence of the encounter demonstrates that serious or irreversible harm has or will occur?

1. What constitutes an encounter?

To better understand the challenge of detecting evidence of an encounter, it is necessary to understand the extent and nature of potential impacts of a fishing activity. These impacts can be categorized into three primary pathways of effects:

- **Direct capture** of organisms or habitat structures by the fishing gear, whether or not they are retained or subsequently released before the gear is retrieved;
- **Physical impacts** of the gear on species or habitat features, that does not constitute even temporary capture (e.g. longlines being dragged along the bottom that may break or damage fragile stationary organisms, mobile gears leveling bottom topography); and
- **Indirect impacts** by gear on organisms, habitat features, or community form and function (e.g. smothering a VME by bottom sediment stirred up by mobile fishing gear, changing abiotic and/or biotic components of an ecosystem as a result of discarded bycatch mortalities).

The occurrence of any of these pathways constitutes an impact of the fishing gear on a VME if the species or habitat feature that is impacted meets any of the criteria for VMEs in paragraph 42 of the *Guidelines for the Management of Deep-Sea Fisheries in the High Seas* (FAO 2008).

Direct capture and release

Direct capture is the easiest of the effects to detect. Even so, detection is still not without error. In very large catches it is unlikely that a single observer will be able to identify and record all the organisms in the retained catch, and the detection of VME organisms may vary based on how the catch is handled as well as the sampling priorities set for the observer. In addition to the detection of capture, evaluation the seriousness of an impact will require an estimate of the

probability of survival of captured organisms that are released. For fragile benthic species it may be standard to assume they will not survive. For more "robust" invertebrates (e.g. leathery epidermis or shells that are not brittle) and some fish species it is often difficult to determine survival rates. Post-release mortality of many species can be high, and varies with a number of factors such as size of the catch and handling practices (FAO 2009).

A second source of uncertainty associated with direct capture occurs when the captured organism or habitat feature is not retained by the gear before retrieval of the gear is complete. For example, this can happen if the organism or feature is fragile and the mobile gear continues to be towed after the capture takes place. Even if the intact organism or feature is large enough to be retained by the mesh, it can be broken into fragments while being dragged along the seafloor, and smaller pieces may be subsequently lost through meshes. Depending on the fragility of the organisms or feature and the duration of post-capture towing, some or all evidence of the encounter may be lost before the gear is retrieved and examined on deck.

To reduce some of the errors associated with the uncertainties described above, enhancements of observations can be made by collecting photographic information of the total catch prior to catch processing and observer sample collection. Ship-based cameras have been utilized as a method to validate bycatch logs on smaller vessels not capable of carrying observers. One drawback to the photographic data is that the analysis is post-fishing and will not address the need for immediate reporting. Another is that unless photographic methods for observation of the catch during the time gear is fishing are used, the methods still do not provide information on catch that is damaged but not retained when the gear is retrieved. During research trawl surveys the lead author has found that examination of trawl footrope gear or net meshes when the trawl is recovered enhances detection of organisms or habitat feature that are often not present in the processed catch.

<u>Physical impact with no capture</u>

Direct physical damage to organisms or habitat features without capture can occur for a number of reasons including:

- Gear impacts may dislodge, injure or kill sessile or inflexible organisms without capturing them in the gear.
- Some gears are very selective in what organisms they retain, and the catch can be a poor indicator of true extent and nature of the physical fishing impact.

For flexible, sessile, or low mobility organisms, the gear may dislodge the organism from the substrate. In this case the extent of the damage will depend on the organism's ability to re-establish itself. It has been speculated by Gilkinson *et al.* (2003) that some soft corals attached to dead clam shells appeared to get washed away by the bow wave of clam dredge gear but could re-establish themselves. In working with sea pens, such as *Ptilosarcus gurneyi,* in an aquarium setting the lead author has observed that they are capable of retracting into the substrate when touched or can rebury if dislodged. In experimental work simulating trawl impacts, Malecha and Stone (2009) found that for larger sea-whips (*Halipterus willeomoesi)* only 50% of the dislodged organisms were able to initially right themselves. However, most of these eventually were dislodged again without further disturbance. In addition, Malecha and Stone (2009) found that during the period when these organisms were dislodged, they were more vulnerable to scavenging predators, such as nudibranchs, which resulted in increased damage and mortality.

Detecting evidence of physical impact is especially problematic with longline gear or traps where most of the impact may be due to the gear being dragged along the bottom without direct capture of the organisms in the hooks or traps (Sharp *et al.*, 2009).

Evidence to detect these types of impacts has been collected using head-rope cameras on trawls. In research applications such cameras have been used to identify organisms in the path of the trawl and to estimate their catchability coefficients. Sharp *et al.* (2009) have also used cameras on longline gear to estimate the area of impact and quantify the extent and nature of their encounters. However these methods may not be practical in a commercial setting.

As mentioned in the previous section, post-fishery processing and analysis of photographic data makes it impractical, as yet, to use such methods for real-time management of serious adverse impacts on VMEs. However, even if the on-deck images could be processed in real time, they would still not be informative about catch that had not been retained.

A different approach to address this issue is being used in New Zealand through a system of indicator taxa that co-occur and/or have a symbiotic relationship with VME and have a higher likelihood of retention in the catch then does the VME of concern (see discussion below regarding detection of VME communities).

Indirect impacts

Detecting indirect impacts, such as disruption of the bottom causing siltation and smothering of sessile organisms, is perhaps the most challenging impact to detect. The nature of the impact, such as re-suspension of sediments, will not be reflected by whatever is retained by the gear - even temporarily - and the organisms suffering the impacts may not be in the immediate path of the gear. Even the use of undersea photographic approaches to detect such encounters may be problematic because the effect itself (for example, siltation) may obscure the visual field of the camera and because the organisms suffering the impacts may not be in the visual field.

Consequently, "evidence" of such encounters may have to be inferred from overall knowledge of the substrate types responsible for the indirect effects and the known occurrence of VMEs susceptible to the indirect effect. For example, the Pacific Region of Canada is endeavouring to set boundaries around known VME (in this case glass sponge reefs) that take into account siltation caused by bottom-trawling in the region. The proposed approach is to compile information on the bottom currents in the area, seabed morphology and sediment type, and model the sediment movement (i.e. amount, distance, and direction) from the impacted area onto the VME. This approach is only effective when the appropriate oceanographic information is available. In areas where information on bottom current and bottom type is unknown, these properties may in part be determined by information from sounders and head-line instrumentation, such as cameras and current meters, which are often used on vessels as they fish. Such information still needs to be complemented by information on the likelihood or presence of a VME vulnerable to siltation in the area. Although such information does not indicate to a vessel operator that a VME has been encountered, it may help inform management decisions on the minimum distance and directions that a vessel should move if a 'move-on rule' were to be applied.

Other indirect impacts, such as changing community structure (e.g. more scavengers) or physical conditions (e.g. excessive biological oxygen demand), will take time to express themselves. Their use as indicators for real-time management of serious or irreversible harm is even more problematic, and they should be addressed in the overall management strategies used in the fishery.

2. Evidence of an encounter

Whatever the evidence that may be available, it is necessary to have established protocols on which to base a conclusion that an encounter with a VME has (or has not) occurred. The basis for such a conclusion, and the approaches to making them, depends on many factors, including whether the encounter is with a VME defined at the individual, population, or community level.

Individual level

At the individual level, conclusions about an encountered organism being a VME require identification of the organism. Identification can be difficult with taxa that are cryptic or otherwise difficult to identify (sometimes needing specialized equipment), with the discovery of known species in novel locations, or perhaps even the discovery of a new species. In New Zealand fisheries some of these problems have been addressed through the development of easy to use identification picture keys and a sampling protocol (Parker *et al.*, 2009). If the identification of the individual at sea is too complex, specimens are identified to a higher taxonomic level that is easier to determine, and samples are retained for post-fishery identification. The sample collection, retention, and post-fishery identification component of this strategy does not support a real-time encounter protocol operation, but does contribute to improving the overall framework over time.

Population level

The federal *Species at Risk Act* in Canada and the Convention of Biological Diversity are not only concerned with the protection of biodiversity at the species level, but also at the population level. Traditional fisheries management is usually done at the population level as well. Historically, populations have been delineated on a variety of grounds including perceived discontinuities in range, morphometric differences, genetic evidence, unique parasite loads, etc., or is circumvented by managing on the finest spatial scale possible (e.g. geoduck management in British Columbia on a bed basis).

Population structure is particularly relevant to encounter protocols when applying mitigation measures at the time an encounter is detected. If the goal of the protocol is to protect particular populations from impact, information on the population structure needs to be available when the measures are designed. New Zealand is looking at a mechanism for implementing distance-based criteria into their decision framework (Parker *et al.*, 2009). However, on a case-by-case basis it is unlikely that an observer or fisheries operator could identify exactly which population of a species had been encountered. Rather, when there is a desire to apply conservation measures at the population scale, the design of the whole framework for how a vessel and fleet would respond to an encounter would have to take account of the spatial distribution information available for the population. Mitigation measures would have to be ones likely to reduce impact on the whole population and not just on a single aggregation of it..

Community level

Some unique communities are likely to meet the FAO criteria for VME. In such cases it may be possible to specify a small number of diagnostic taxa that can be identified readily, and if present in a catch, can be taken as indicative of the presence of the larger community of concern. Examination of the catch for the presence of diagnostic species may be a more practical strategy for supporting a decision about an encounter with that type of VME than trying

to evaluate the presence of the entire community. This is similar to the aforementioned strategy of using indicator taxa for related VME species that are not retained in catch.

In New Zealand fisheries, observers record the number of certain vulnerable taxa present in the catch, allowing captains to monitor when they are operating in an area supporting a vulnerable community (Parker *et al.* 2009). The premise is that high biodiversity areas often meet the criteria for VMEs, and particular (ideally conspicuous) taxa are only present in areas of high diversity. Thus, monitoring the presence of certain types of organisms in the gear will give an indication if the activity has impacted a high biodiversity area, and, therefore, likely impacted a VME.

3. Thresholds for defining an encounter

Regardless of whether or not evidence is available during fishing operations that an encounter may have occurred, decisions on encounters may not be binary - where a binary decision would be that *any* evidence of the presence of a VME during fishing operations means an encounter has occurred and no evidence of an encounter indicates with certainty that no encounter has occurred. When evidence of a possible VME is present in fishing gear, for example, there still may need to be some quantitative threshold that must be exceeded before it is concluded that continued fishing in the area would pose an unacceptable risk of serious or irreversible harm (or that such harm may have already occurred). Alternately, absence of a VME in fishing gear or catch may not be an adequate basis for concluding that there is a low risk of further fishing causing serious or irreversible harm.

Developing a non-binary response is complex. Setting a quantitative threshold to indicate the presence of a VME in the catch or gear is considered a tractable approach to making decisions about whether and under what conditions to allow continued fishing in an area where there is evidence of a possible encounter with a VME. Currently, RFMO/As use threshold weights or volumes which, if exceeded in a catch, trigger a management action. Auster *et al.* (2010) provides a table of thresholds used by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), the North Atlantic Fisheries Organization (NAFO) and the Southern Pacific Regional Fisheries Management Organization (SPRFMO). They point out that there is neither consistency between RFMO/As in where these thresholds are set, nor in the rationales provided for their positions, even though they all claim to have conservation value. Auster *et al.* (2010) do not reject the concept of thresholds or triggers. However, they conclude that thresholds currently in use provide few conservation benefits to VMEs. This is primarily due to the fact that thresholds are not derived from any explicit demonstration of biomass–density relationships that produce a critical threshold for a VME, nor, in most cases, has there been an evaluation of catch efficiency in fishing gear required for standardizing catch rates. More and better science will be needed to set effective thresholds.

The problem of absence of evidence of a VME not being equivalent to absence of an encounter between a fishing operation and a VME is more difficult. In preceding sections, possible approaches, such gear-mounted camera and model-based methods using substrate, oceanographic, and biotic data for evaluating risks of smothering, were proposed. However, none of these approaches are operational at this time. Modern forensic genetic methods are being explored for real-time stock identification in fisheries, and it is possible that in the medium term such technologies may provide cost-effective methods as well. However, in cases where features that are VMEs are unlikely to be retained in the fishing gear, there are few practical alternatives to only authorizing fishing in areas where such features are unlikely to be encountered to begin with.

THE MANAGEMENT RESPONSE: MOVE-ON RULE

Once a VME has been detected and the threshold triggering a management action has been met, the final issue in the process is to determine the appropriate management action. The FAO *Deep-Sea Fishery Guidelines* (FAO, 2008) require that when an encounter has occurred, the management response must include reporting the encounter (including the location and nature of the VME), ceasing to fish in that area, and implementing an appropriate mitigation measure before recommencing fishing. The most typical mitigation measure is to move at least a specified distance to a new location. In the case of the SPRFMO and the New Zealand Ministry of Fisheries the rule is to move an arbitrary five nautical miles away from the VME. The problem with the arbitrary move, as pointed out by Parker *et al.* (2009), is that it could cause additional serious or irreversible harm to VMEs in the new area depending on the size, patchiness, spatial distribution, and separation of the VMEs. Moreover, when a single tow of mobile fishing gear can extend into the tens of kilometres, it may be impossible to determine at what point in the fishing event the encounter actually occurred, so the starting point for the move may be difficult, if not impossible, to determine.

THE PROPOSED ENCOUNTER PROTOCOL

A fisheries management system that utilizes spatial management controls is essential to implementing most encounter protocols. In its simplest form, such a control system could open specific areas where the likelihood of encounters with VMEs is known to be low or where conditions for detecting an encounter reliably and quickly are good, while all remaining areas are closed. This contrasts with a system that consistently opens all areas to fishing impacts, even areas where there is no history of fishing, except when there is strong evidence to support a targeted closure.

The encounter protocol proposed in this paper describes a spatially-based decision making process. Decisions to allow fishing and/or implement an encounter protocol are based on the calculated risk of fishing activity in a given area causing serious adverse impacts (SAIs) to VMEs. The proposed encounter protocol has six components, which are closely aligned to the five process steps outlined in the SBA policy (see above). The six components to the proposed encounter protocol are:

1. Assemble and map the distribution of VME;
2. Assemble and map the extent of human impacts;
3. Use information on VME distribution and human impacts to infer the current status of the VME;
4. Conduct a risk analysis;
5. Determine management measures and implementation; and
6. Monitoring and evaluation.

1. ASSEMBLE AND MAP THE DISTRIBUTION OF VME

In the first step of the encounter protocol, all available information on the distribution of the VME being considered is assembled and mapped. Where observational records from fishery reports or research surveys are available, these should be mapped and contoured according to methods advised at the Canadian Science Advisory Secretariat (CSAS) national science advisory process on corals, sponges, and hydrothermal vents (DFO 2010a). In areas where these records are considered to accurately capture the presence of VMEs, such contour maps can be used to determine the distribution of the VME.

However, in many areas within Canadian waters and particularly in areas beyond national jurisdiction, there are insufficient data to fully delineate the distribution of VMEs. In those cases, observational information should be augmented with predictive models. Species distribution models (SDM) produce maps of predicted suitable habitat by relating known locations of VMEs to key biotic and abiotic features, such as oceanographic, geomorphologic, and bathymetric data. Model results provide gridded predictions of habitat suitability, which may also be interpreted as the likelihood of VMEs being present in that area. Models predicting suitable habitat for four orders of coral in British Columbia are presented by Finney (2010). An example of habitat suitability for the coral order Alcyonacea is presented in Figure 1. In this example, a 500m x 500m grid was used, with each grid cell having a prediction of habitat suitability ranging from 1.0 (perfectly suitable habitat) to 0 (completely unsuitable habitat). The spatial resolution of models can be modified on a case-by-case basis depending on management needs, biological relevance, and the spatial resolution of available data. Validation of the model predictions by in situ investigations is always desirable. However, failure to find a VME in areas predicted to be highly suitable may not be a prediction error. It is possible that VMEs were there in the past but have been removed by human activities or excluded through other ecological processes. Hence the validation step may not be completed until after Step 2 is complete.

2. ASSEMBLE AND MAP THE EXTENT OF HUMAN IMPACTS

Human impact mapping requires information on the extent and intensity of human activity in the area of interest. For example, in the case of a trawl fishery, the extent of impact of a single tow can be estimated by multiplying the width of the trawl or door spread by the length of the tow (as calculated using a straight line between reported start, mid and end points). The extent of the entire fishery can then be calculated by mapping all fishing events. The intensity of impact can be derived from metrics such as the number of fishing events in a given area, or the proportion of a given area that has been fished, per unit of time. Some of this type of mapping has already been completed for mobile fishing gears and was peer-reviewed at previous CSAS national science advisory processes on the general impacts of trawl gears and benthic dredges (DFO 2006a, 2006b, 2010b, 2010c).

If possible, human impacts should be mapped at the same spatial scale used to map the distribution of VMEs. The temporal scale used should take into account the expected recovery potential rate for the VME of concern using appropriate methods to estimate the likelihood and trajectory of recovery. An example of such mapping is shown in Figure 2. Methods used for quantifying the distribution and extent of the British Columbia bottom trawl fishery in this example were developed in a joint project with DFO, Simon Fraser University, and industry (Grinnell *et al.*, in prep). These methods were used to analyse the proportion of each grid cell impacted by bottom trawling over a fourteen-year period (1996-2009). Analyses were conducted on the same spatial scale (i.e. cell size and extent) as the habitat modelling described in Finney (2010) and presented in Figure 1.

3. INFER CURRENT STATUS

Combining SDMs with human impact mapping can produce a map of the inferred **current status** of the area a VME occupies, where "current status" is considered to be the probability of the VME existing following disturbance (Figure 3). This calculation must be informed by data on the vulnerability of the VME of interest to specific impacts.

By comparing the spatial extent of the VME calculated in step (1) above with the spatial extent of the **current status** in the present step, one can calculate both the absolute and proportion of undisturbed potential habitat left for the species, unique habitat, or community. The estimate of the amount of undisturbed potential habitat will depend on the threshold value

of habitat suitability that is selected as the cut-off to distinguish between predicted presence and predicted absence of the VME. The higher the threshold of habitat suitability required for concluding the VME is present, the smaller the estimate of its spatial extent (Figure 4). However, if all decision-making is done in an analytical risk management framework, the setting of thresholds for binary decisions may not be needed, as the full likelihood profile can be used by advanced risk quantification and risk management software.

Managers can use this information in advance of any proposed fishing activity in areas covered by the SBA policy to evaluate the likelihood that the proposed fishing may encounter a specific VME feature. In addition, managers will have estimates of the proportion (Figure 4) and the actual area (Figure 5) of habitat impacted by fishing for different levels of habitat suitability. For example, if a fishery was proposed for the first time in an area where the predicted habitat suitability for the coral order Alcyonacea was less than 0.3, managers will know that 48% of habitat predicted to be more suitable has already been impacted.

4. CONDUCT A RISK ANALYSIS

Once the current status of a VME has been determined, a risk assessment should be conducted to determine the likelihood that fishing in a given area will cause serious or irreversible harm to VME. In Canada, guidance for defining serious or irreversible harm is taken from the UNGA *Resolution 61/105* and the *FAO Deep-Sea Fishery Guidelines* (see Introduction).

In this situation, risk is the product of the probability of an encounter occurring, and the potential severity of the consequences of an encounter. The probability of an encounter will be determined by the current status of the VME (i.e., the probability of the VME existing in an area given previous human impacts) and the probability of the proposed activity encountering the VME, as not all proposed activities will have an equal probability of encounter. For example, it is less likely that a mid-water trawl will encounter a benthic VME than it is for a bottom trawl to encounter the same VME.

The second component of risk, the potential severity of the consequences of an encounter, will depend on the nature of the proposed fishing activity and the specific biological traits of the VME in question, as not all individuals, populations or ecosystems will be equally impacted by an encounter with fishing gear. As mentioned in previous sections, the potential impacts of some fishing gears have been reviewed in CSAS national science advisory processes on the general impacts of trawl gears and benthic dredges (DFO 2006a, 2006b, 2010b, 2010c), though further research may be needed on the specific impacts of some gears. The biological traits of VME, particularly the **fragility** and **vulnerability** of VME to specific impacts, must then be considered and incorporated into the estimate of the potential severity of consequences of an encounter. CCAMLR defines these terms (Sharp and Parker, 2010) as:

Fragility: The susceptibility of an organism (or habitat) to impact (physical damage or mortality) arising from a particular interaction with a particular type of threat e.g. bottom trawls or longlines. Fragility refers to an intrinsic physical property of the organism and the nature of the threat, without reference to the actual presence or intensity of the threat. Example: Tall, brittle organisms would be more fragile as a result of shearing forces exerted by lateral longline movement than low profile or flexible organisms.

Vulnerability: The susceptibility of species (or habitat) to impact by a particular type of threat over time, without reference to the actual presence or intensity of the threat. Vulnerability incorporates fragility but also includes other spatio-temporal and ecological factors affecting the resistance or resilience of the species (or habitat) to impact, and/or the potential for recovery

from impact over time (e.g. longevity, productivity/growth rate, dispersal and colonization, rarity, community/ habitat patch size, succession and spatial configuration).

The biological traits, fragility and vulnerability of many VME in Canada are not well understood at this time, and will likely have to be derived from the literature on similar species and utilized in a precautionary manner. In Europe, there is a coordinated effort to provide consistent information on a number of these factors by having researchers submit peer reviewed information to a common Biological Traits Database of European Atlantic Species. This type of data has proven useful in providing indices of ecosystem health and functioning using a variety of analytical models such as Biological Traits Analysis (Bremner *et al.*, 2006) and Biotic Coefficients (Borja *et al.*, 2003).

In addition to providing an inferred current status of VME, the results of the first three steps of this framework can help determine the vulnerability of a VME by providing information on:

i. The predicted suitability of the habitat for the VME in the area proposed to be impacted;
ii. The absolute amount of various qualities of predicted suitable habitat in Canadian waters and the proposed area;
iii. The proportion of habitat of various qualities that has already been and/or may be impacted by future human activities; and
iv. The spatial characteristic of potentially suitable habitat in relation to other suitable habitats (i.e., if they continuous or separated and isolated).

Evaluating the calculated risk of inflicting serious or irreversible harm on VMEs can be facilitated by using decision support tools and developing appropriate decision rules, such as establishing target and limit reference points.

5. MANAGEMENT MEASURES AND IMPLEMENTATION

Following the risk assessment managers must decide whether or not to allow fishing in a given area (one or more grid squares as described in step 1) based on the risk of inflicting serious or irreversible harm on a VME. It is important to note that risk of causing serious or irreversible harm may not be equally weighted for all VME. There may be mitigating circumstances that may make a manager more risk averse when deciding to allow fishing in a given area. Such circumstances may include:

- The *absolute* amount of a specific VME type – the rarer the type, the greater the concern.
- The *relative* amount of a specific VME type – the more of the type that has already been impacted, the greater the concern about what is left.
- The *isolation* of the specific occurrence of the VME – the more isolated the occurrence, the greater the concern.
- The *probability of detecting an encounter* – the more difficult it is to detect encounters the more precautionary you should be.

When making decisions regarding whether or not to allow fishing, managers have three main options: 1) do not allow fishing; 2) allow fishing with no encounter protocol; or 3) allow fishing with an encounter protocol in place.

If there is an unacceptable risk that fishing will result in an encounter with a VME that causes serious or irreversible harm at the individual, population, or community level managers may decide to prohibit fishing, or certain types of fishing, in a given area. Conversely, in areas where the risk is very low, managers may decide to allow fishing with no encounter protocol in place. This may occur in an area that has completely unsuitable habitat for the VME of interest, or in areas where past fishing has been so intense that it is unlikely that there are intact VMEs.

There will also be many areas where there is an acceptable but non-zero likelihood that SAIs may be inflicted on VME during the course of fishing activity, and areas where there is insufficient information to estimate risk. In such places a manager may decide to allow fishing, but have an encounter protocol in place to avoid further harm to VME if they are encountered by fishing vessels. In such a scenario a second stage of decision making must occur do define the evidence and thresholds required to identify an encounter (see sections above for discussions). Decisions must also be made on the nature and extent of appropriate management actions if a VME is encountered. For example, if a 'move on rule' is selected as the management action, it could be designed to move the fishing activity to a region with a lower calculated risk for causing a SAI. For example, if a fishing vessel has an encounter with a VME in an area that was calculated to have a 0.6 probability of causing serious or irreversible harm, the vessel may be required to move to an area calculated to have a lower probability of causing serious or irreversible harm.

6. MONITORING AND EVALUATION

The final step in this framework is to monitor encounters and evaluate whether or not the encounter protocol is meeting management and conservation objectives. Encounters with VME should be documented in real time when possible (i.e. when the encounter can be detected in the catch), or post-fishing when real time is not possible (e.g. video analysis). New information should be used in updated models and analysis conducted in Steps 1-3 above, and results should be re-assessed in the risk analysis. The effectiveness of the encounter protocol should be evaluated, and changes to the protocol should be made as needed.

MOVING FORWARD

This proposed encounter protocol framework provides a potential assessment and decision making system, even for situations where there is limited data. It also provides an adaptable system which can be modified as new information becomes available. To implement this protocol the following steps are necessary:

1. Develop and validate species distribution models, human use maps, and combination models that fully integrate spatially explicit information from oceanographic, hydrographic, and biological assessments;
2. Assemble and properly manage DFO and non-DFO data that will be used in models and risk analysis, including a Biological Traits Database, so that model input parameters can be readily updated and can routinely be run to provide managers with the most up-to-date results;
3. Develop identification tools for use in the collection of proper biological information by observers, DFO Science, and other researchers;
4. Undertake further research to quantify the extent and nature of impacts of fisheries activities on biodiversity, habitat, and ecosystem health to be used in the risk analysis;
5. Continue developing quantitative risk assessment indices that can be used to determine risks to VME (species, habitats, ecosystems) and the ecosystems of which they are part; and
6. Further develop limit reference points for impacts to protect VMEs from significant and irreversible harm, and evaluate the effectiveness of various risk tolerances.

This proposed encounter response protocol and the tools developed for its implementation can be easily adapted to provide advice to resource managers addressing non-fishery related human benthic impacts that could cause serious or irreversible harm to VMEs.

FIGURES

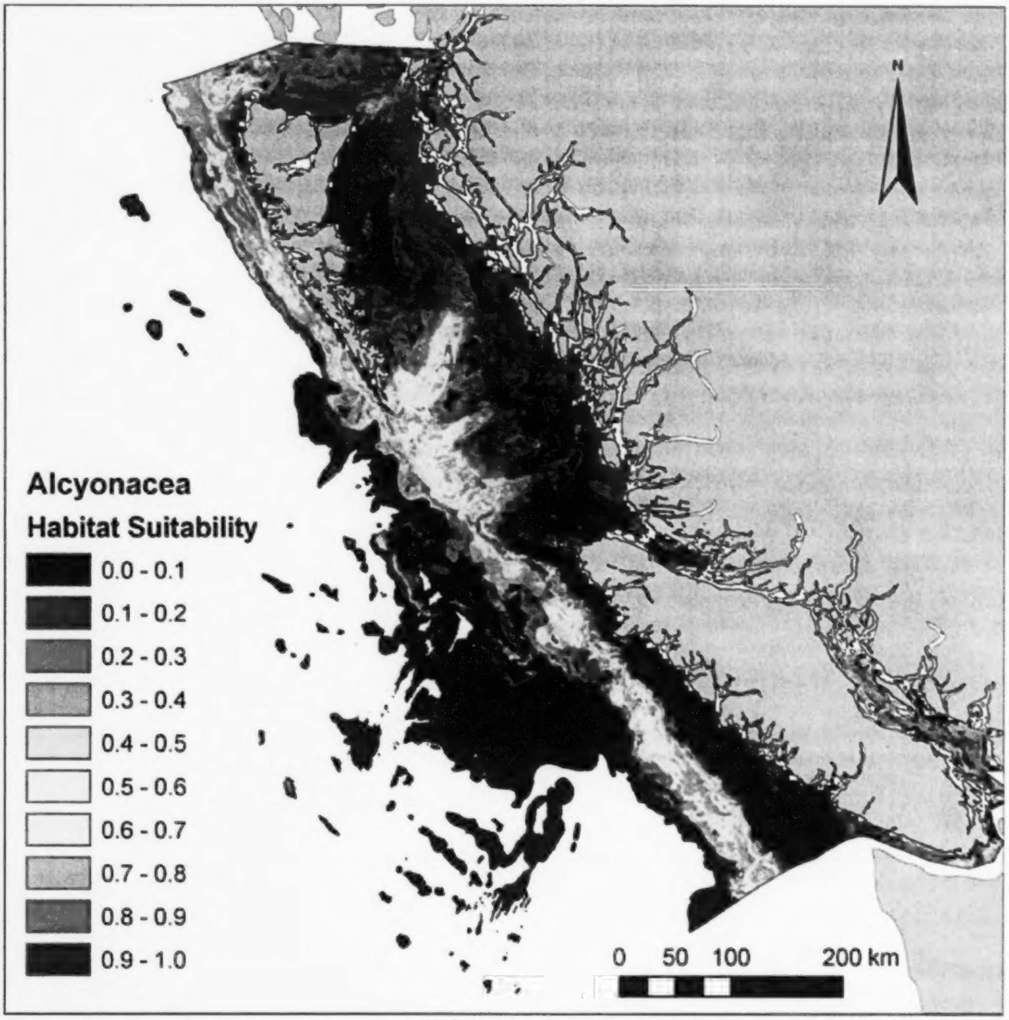

Figure 1: Distribution of predicted suitable habitat for Alcyonacea coral. The gradient from 0 (blue) to 1.0 (red) indicates lower to higher suitability.

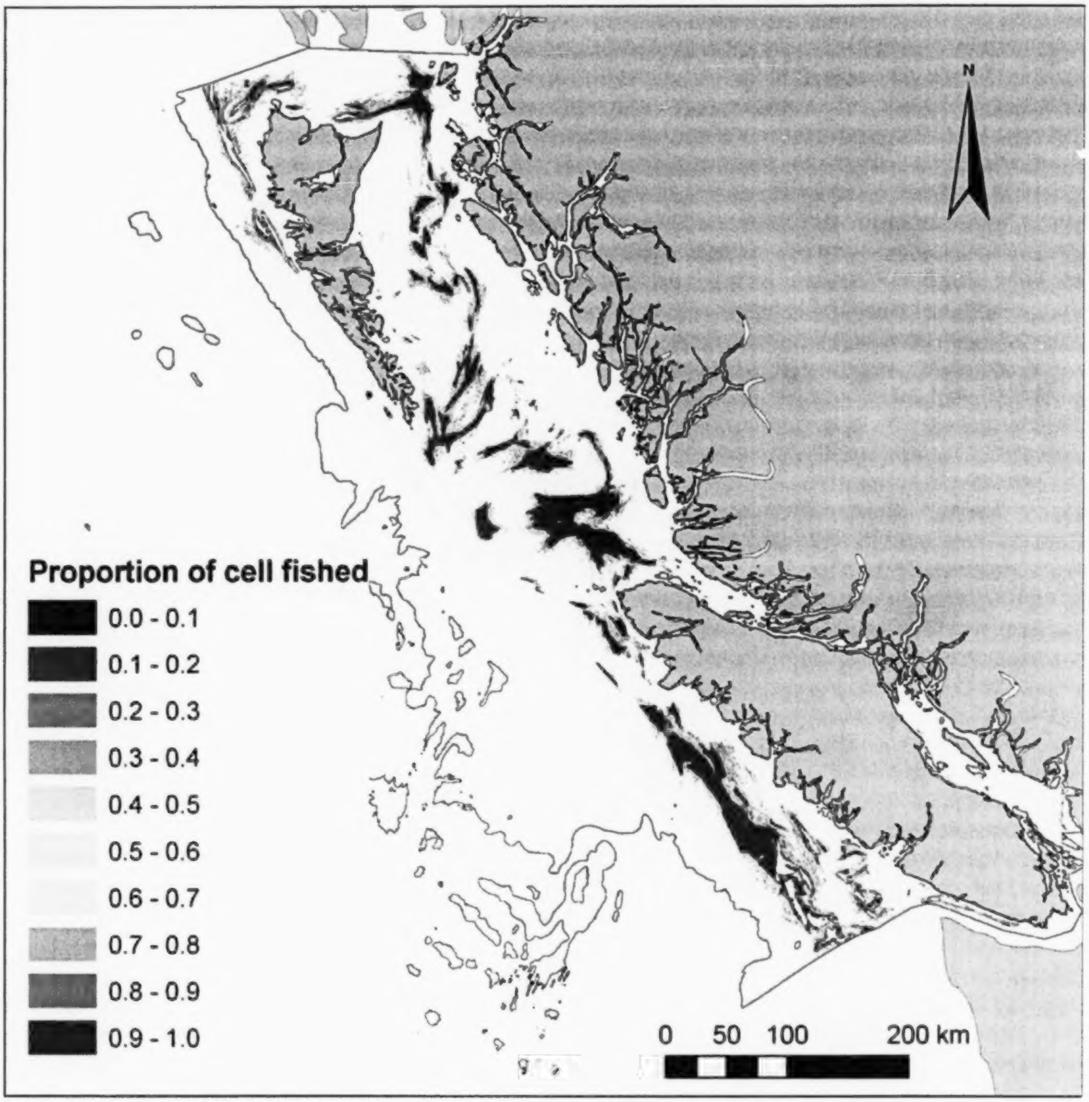

Figure 2: Spatial distribution and the cumulative proportion of each 500 m by 500 m cell fished over a fourteen-year period (1996-2009). For privacy reasons, only areas where at least three vessels reported fishing activity are displayed

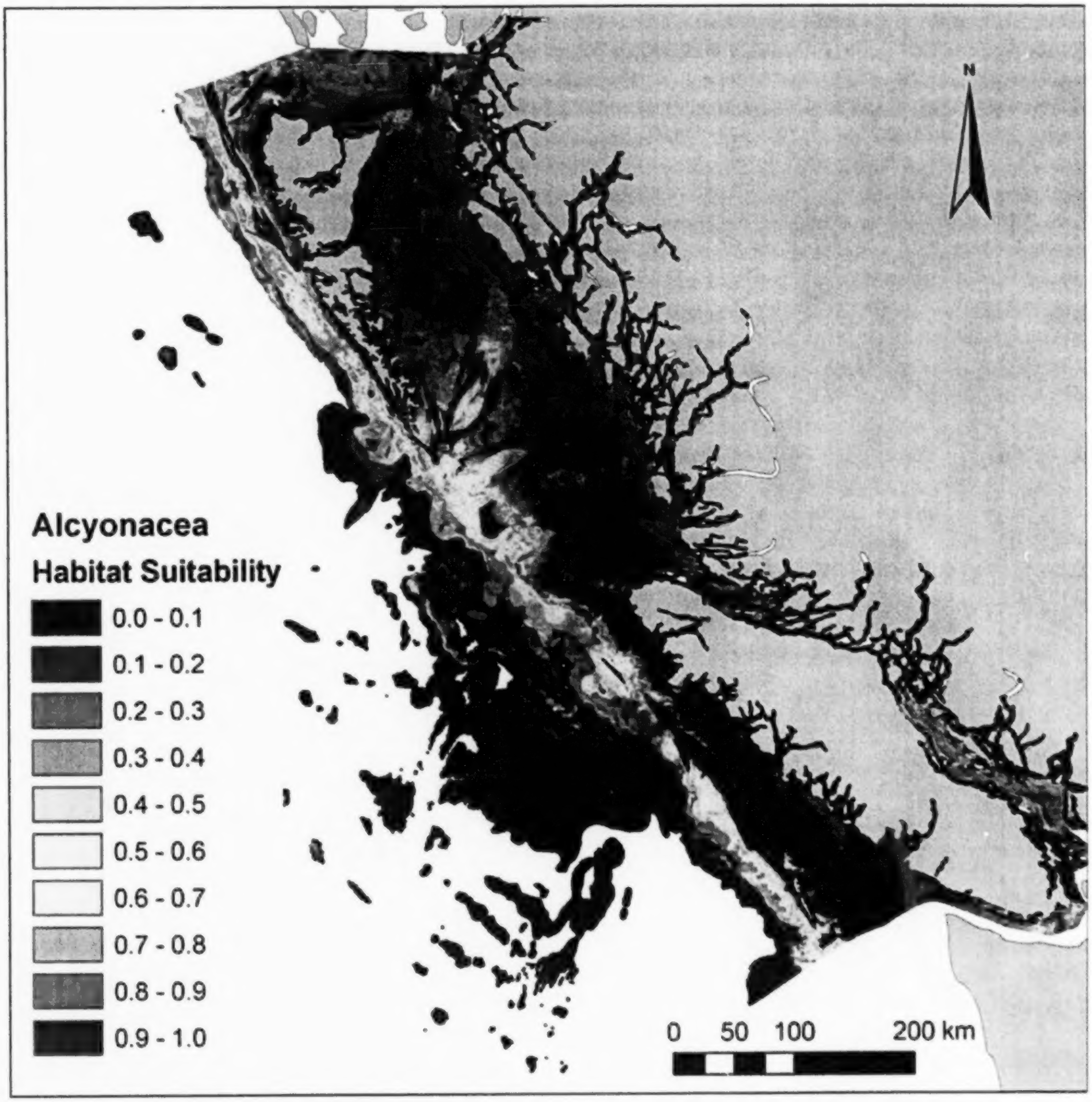

Figure 3: Predicted current status of the suitable habitat of a species after taking fishing impacts into account (habitat suitability x impact).

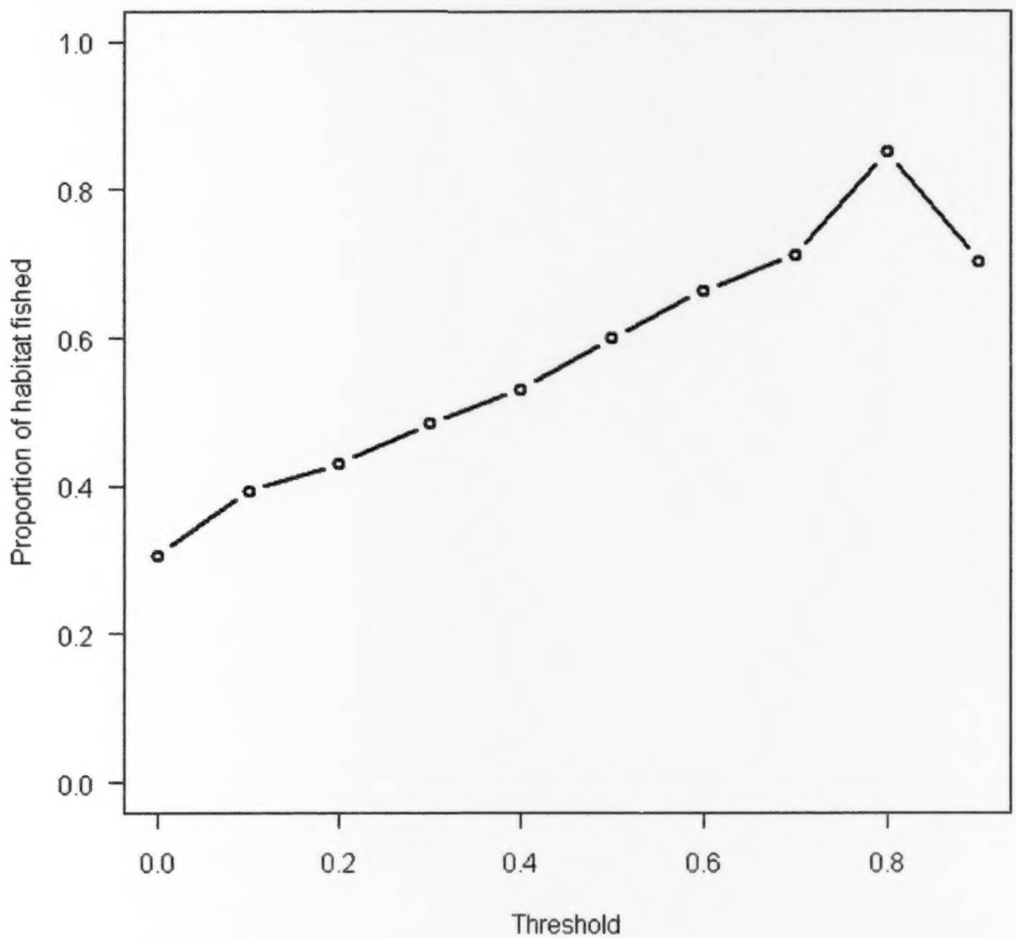

Figure 4: Proportion of area fished by the groundfish bottom trawl fishery when using different cut-off points to distinguish between predicted suitable and unsuitable habitat for Alcyonacea. A threshold of 0 indicates the proportion of the entire study area that is fished. Generally the proportion of habitat potentially impacted by fishing activity increases as the threshold increases, indicating that fishing tends to be disproportionately concentrated in areas predicted to be more suitable for coral.

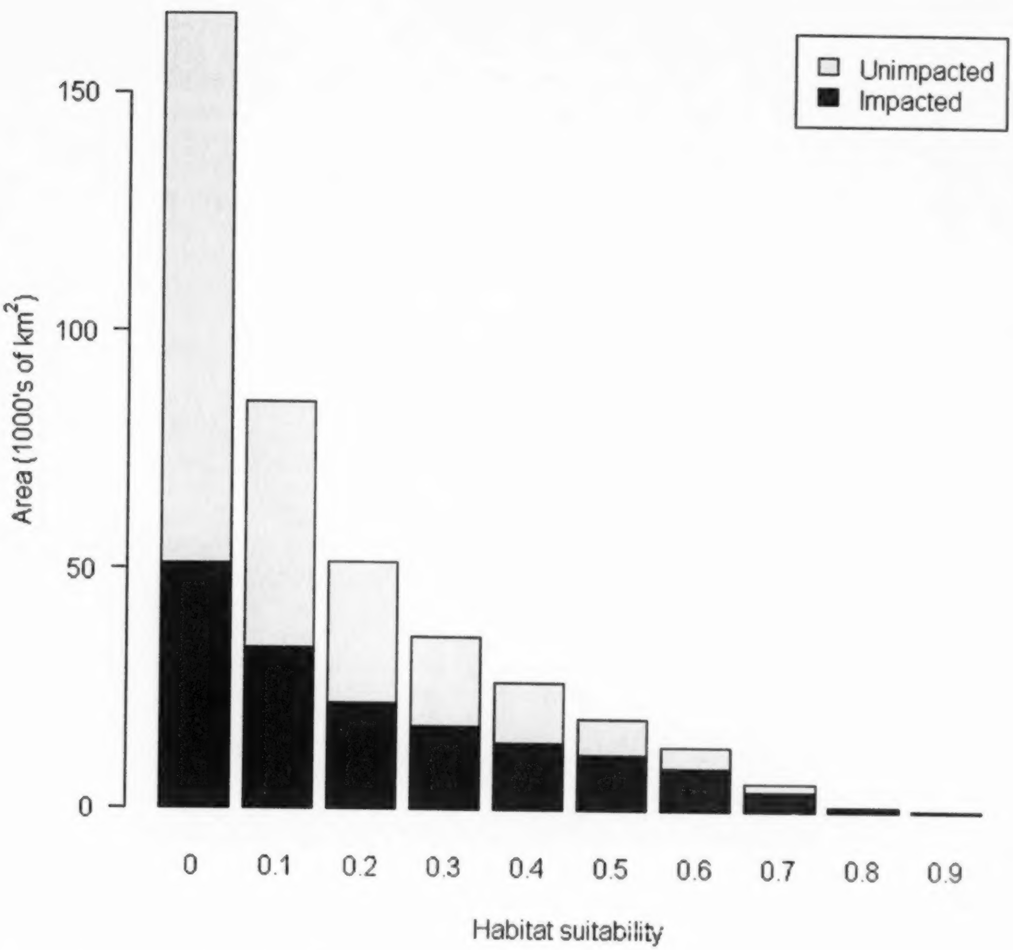

Figure 5: Area (1000's of km^2) of unimpacted (light grey) and impacted (dark grey) predicted suitable habitat at differing levels of habitat suitability for Alcyonacea.

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